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POTENTIAL OF LAND USE MAPPING IN THE TVA WITH HYPER-ALTITUDE AND SPACE PHOTOGRAPHY

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POTENTIAL OF LAND USE MAPPING IN THE TVA WITH HYPER-ALTITUDE AND SPACE PHOTOGRAPHY

Introduction

The purpose of this study has been to evaluate the potential of using selected remote sensing systems to monitor the environment of the Tennessee Valley. Specifically, the goal was to determine to what degree hyper-altitude and space photography could be used to satisfy the Tennessee Valley Authority's information needs regarding land use. Requirements and types of land use data requested by the TVA were obtained by two processes: (1) be referring to Technical Report 71-2, Delineation of Information Requirements by T.V.A. Interviews, by J. B. Rehder and (2) by consulting with TVA personnel in Chattanooga on February 25, 1972. Specific attention was given to the land use needs listed by the Soils and Fertilizer Division.

Methodology and Study Area

Color photography and color infrared photography of the northern Alabama area of the Tennessee Valley were obtained on two separate occasions, May and November of 1971, at two scales, 1:60,000 and 1:120,000. In addition, 70 mm. color and color infrared photography (scale approximately 1:340,000) was acquired on the November flight. In light of the TVA requirements it was decided to study each set of imagery to discern exactly how much information and what type could be extracted at each scale. This work was done in the following manner.

The color and color infrared imagery at a scale of 1:340,000 was felt to closely approximate the best imagery expected from space by the ERTS-A satellite. This imagery was studied and an estimate made of its practical applications for delimiting small-scale land use regions and agricultural systems. The next step involved an analysis of the 1:120,000 scale imagery flown in November. Six test sites of approximately 25,000 acres each were selected to determine if such imagery could be used to detect variations in land use within test sites and between test sites (i.e. in different land use subregions). Last, a seventh, smaller test site was selected for a more detailed analysis of land use using color infrared photography at a scale of 1:60,000.

The realization that a successful interpretation strategy for one small section of the Tennessee Valley might not be successful over the entire area caused us to consider several varied sites for analysis. Selection of the seven test sites was based on variations in topography, vegetation, as well as land use. The sites are from the following areas: Anderson, Moulton-Courtland, Redstone Airport, Hollytree-Paint Rock River, Scottsboro, and Sand Mountain in Alabama, and Hales Bar in Tennessee (Figure 1). An attempt was made to select from the available imagery, sites which would be typical of as many varied land use types as possible. Each site was selected as characteristic of different land use subregions. For example, Site I from the Anderson area is in a region of karst topography, while Site III from the Redstone area is part of one of the better agricultural areas in the Tennessee Valley, and Site V, the Scottsboro area, is a varied site with lowlands, plateau uplands, and steep forested slopes. Each test site and its distinguishing characteristic(s) are listed in Table I.

TABLE I

TEST SITES

SITE	AREA	DISTINGUISHING CHARACTERISTIC(S)
I	Anderson, Alabama	Fine Textured, karst topography, small fields
II	Moulton-Courtland, Alabama	Large and small fields, forest
III	Redstone Airport, Alabama	High quality agricultural land large fields
IV	Hollytree-Paint Rock River, Alabama	Dissected plateau, large lowland fields
V	Scottsboro, Alabama	A varied site, contains lowlands, plateau uplands, and steep forested slopes
VI	Sand Mountain, Alabama	Ridge and valley, plateau
VII	Hales Bar, Tennessee	Dissected plateau, mostly forest

Tennessee Valley test sites for use with hyper-altitude photography and their distinguishing characteristic(s).

Land use in six test sites was recorded on a 40 acre cell basis. This method, suggested by Simonett (1969), simulated a mechanized system desirable for monitoring changes in land use and repeated analysis of an area. Although some accuracy is sacrificed, a rapid data retrieval process is retained using this method. The 40 acre cell also corresponds closely to the dimensions of the cell containing a homogeneous category for accrued field discrimination (Schwarz, 1970). Moreover, 40 acres approaches the resolution cell size of imagery expected from space altitudes.

Since no ground data recording actual crop type, or field conditions was accessible for this study it was apparent that any attempt to distinguish between crops was futile. Rather, with imagery at a scale of 1:120,000 only distinctions between crop, pasture, forest, water, and other land use (e.g. settlement, roads, urban areas) were made. Since many fields were smaller than 40 acres and cells did not always exactly outline one field, averaging was required. Specifically, the land use that dominated the cell was classified as the land use of the entire cell. Using this process the imagery was examined under magnification to determine the land use category in the cell. Each cell of each test site was examined by this process.

Following this step, 1:60,000 scale color infrared imagery was analyzed to determine if the cell by cell decision process was easier at a larger scale, and if the decision could be made with a greater degree of certainty. One test site was examined in this manner using the same land use code as that mentioned above. A second part attempted to discover exactly how much detailed land use information could be obtained with this scale of imagery. A ten acre cell was used in this portion of the study using one test site of approximately 9,000 acres. In this test site the imagery was analyzed under magnification according to land use in each cell. A decision was made as to its land use according to types modified from those listed in Tennessee Valley Land and Its Changing Use, July, 1971. This test site was then examined again under magnification and classified according to its land capability using the 10 acre cell unit. These classes were a modified form of the eight classes found in agricultural Handbook No. 210, USDA Soil Conservation Service, 1961, and TVA Bulletin Y-27 Tennessee Valley Land and Its Changing Use, July, 1971.

The last step of this study involved a comparison of types of imagery. The first comparison was between film types, color and color infrared, to ascertain which was better for land use analysis at one particular time of year (May). The second comparison was between scales of imagery. Two test sites were classified according to land use on a 40 acre cell basis for both the 1:60,000 and 1:120,000 scale imagery. By this means, it was possible to determine the consistency of evaluation between scales. Last, using imagery at a scale of 1:120,000, one test site was analyzed for both the May and November flights to determine how well the 40 acre cell approach at this scale could be used to monitor within year change in land use. Simultaneously, an idea of the types of data obtainable at different times of year and the best time of year to image an area was obtained.

As a result of this study it is hoped that an evaluation can be made regarding optimum uses of future imagery of these scales for land use analysis. In addition some idea of the types of data obtainable from space will be known. Lastly, perhaps an aid for data collection will result regarding the monitoring land use and its change in the Tennessee Valley. In the following sections an evaluation is made of each scale of imagery.

Small Scale Hyper-altitude Imagery

As has been mentioned earlier the lack of ground based information was a serious deterrence in the study of land use from the 70 mm. Hasselblad color and color infrared photography (scale 1:340,000). The following is primarily a list of what was seen on the Hasselblad imagery. After evaluating this imagery it was determined that general agricultural land use patterns could be detected. In some cases field patterns were visible, which to some extent, provided information on its agricultural quality. For example, a field which curved around a hillside most likely had a steep slope with a thin soil, and was therefore, of relatively poor quality. Major forest types--evergreen versus deciduous--were also distinguishable due to the red color of the evergreens on color infrared during the winter season. In addition drainage basins could be delimited and land use information for the catchment area (e.g., percent forest) obtained for runoff analysis in hydrology. Limited geologic and geomorphic information was available, but major structural units and slopes were easily detected due to the large area covered by a single photographic frame. Image textures provided clues in detecting topographic variation, e.g. the karst topography of Middle Tennessee versus the plateau of Sand Mountain, Alabama. Visible too, were major transportation networks and power transmission routeways through forests. Urban areas were also detectable and delimitations possible in some cases as to residential and commercial areas.

Most of the items in the above list are gross features, and it is only fair to say that it is in a gross regional view that photography of this scale and resolution is valuable. For those investigators seeking a regional view, imagery of this scale and similar small scale images from space may serve a useful purpose.

Now let us speculate as to additional uses of the small scale Hasselblad imagery. First with the addition of ground based data from a sample area, a training set could be developed. Using this small area as a base it should be possible to obtain more detailed identification regarding land use and analyze large areas. Also, agricultural problems such as flooding and insect invasions might be monitored using such imagery and provide necessary information for control. However, further research with ground data is necessary to determine the degree of detail and exact methodology. Clearly, there is room for additional research in this area.

1:120,000 Scale Imagery

A total of nine frames were selected in order to evaluate the feasibility of obtaining land use information from the color and color infrared photography at the scale of 1:120,000. For each test site an area of 24,960 acres (6½ X 6 miles) was selected, and a grid was placed over the imagery to subdivide the site into 40 acre cells. Then, with the aid of magnification, each 40 acre cell was classified according to its major type of land use. The categories used are as follows: crop, pasture, forest, water, and other land use (i.e. urban and settlement, transportation, and mining). Recording of the classification onto graph paper produced land use maps based on the dominant type of land use per 40 acre cell. These maps are found in Figures 2, 3, 4, 5, 7, 8, 11, and 12. Two flights (one in May and one in November, 1971) and two film types (color and color infrared) allowed comparisons which will be discussed later. Table II lists the number of acres and the percent of the total area in each land use category in the test sites. Notice that differences in types of land use from area to area can be monitored using imagery of this scale. For example, Test Site I near Anderson, Alabama, contained 4,240 acres or 17 percent in crops while Test Site III near the Redstone Airport contained 10,520 acres or 42 percent.

From these data the following observations were made. The 40 acre cell approach in analyzing imagery at a scale of 1:120,000 permits a quick acreage count of land use in an area. Differences among areas can be noted. More importantly, changes in land use across various time periods within a single area or between areas can be detected. Such data of existing conditions should be very useful in predicting future changes in land use as well as the diffusion of certain general agricultural practices.

1:60,000 Scale Imagery

The 1:60,000 scale color and color infrared imagery was the largest scale used in this study. From it, three approaches were employed to obtain land use information: (1) land use maps based on 40 acre cells as before, (2) a detailed land use map based on 10 acre cells, and (3) a land capability classification map also based on 10 acre cells.

First, a land use map (Figure 6) for the Redstone Airport Area,

TABLE II

LAND USE DIFFERENCES IN SIX SELECTED SITES* IN NOVEMBER, 1971,
COLOR INFRARED PHOTOGRAPHY SCALE 1:120,000

SITE	AREA	CROP	PASTURE	FOREST	WATER	OTHER
I	Anderson Area, Alabama					
	Acres	4,240	15,320	5,200	80	120
	Percent	17.0	61.4	20.8	0.3	0.5
II	Moulton-Courtland, Alabama					
	Acres	3,720	8,880	12,280	0	80
	Percent	14.9	35.6	49.2	0.0	0.3
III	Redstone Airport, Alabama					
	Acres	10,520	9,520	3,800	280	840
	Percent	42.1	38.1	15.2	1.2	3.4
IV	Hollytree-Paint Rock River, Alabama					
	Acres	2,960	2,720	19,280	0	0
	Percent	11.9	10.9	77.2	0.0	0.0
VI	Sand Mountain, Alabama					
	Acres	1,680	7,880	14,760	40	600
	Percent	6.7	31.6	59.1	0.2	2.4
VII	Hales Bar, Tennessee					
	Acres	1,480	4,440	13,000	5,080	920
	Percent	5.9	17.8	52.1	20.4	3.8

*Test Site V (Scottsboro, Alabama area) is omitted here as it concerns detailed land use analysis at a scale of 1:60,000.

Site III, was produced from the color infrared photograph of November, 1971, based on 40 acre cells as before. The number of acres by category and percent of the total area is found in Table III. On this larger scale imagery a 40 acre cell is four times as large as before. Therefore, since more detail is visible a more accurate map should be produced, all other things being equal. A comparison of data available on each scale (1:60,000 and 1:120,000) is included in the following section.

During this work it became quite obvious that additional land use information could be gleaned from imagery of this scale and quality. Thus, more detailed studies were designed. These studies are discussed in the following paragraphs.

In order to obtain and map more detailed land use information, two changes were incorporated--the grid cell size was reduced from 40 to 10 acres, and the land use categories were increased from 5 to 25. The resulting categories were modified from the land use types in TVA Bulletin Y-27, Tennessee Valley and Its Changing Use, July, 1971, pages 82-84. We then attempted to make such distinctions as: rows visible or not visible in a crop, improved or unimproved pasture, commercial evergreen or noncommercial deciduous forest, settlement or transportation land use, as well as others. An area of 9,000 acres (3.75 X 3.75 miles) near Scottsboro, Alabama, Site V, was selected for an analysis because it provided a variety of lowland and upland land use types. Figure 10 illustrates the results. The number of acres as well as percent of the total area in each category may be found in Table IV.

For the same site, the Scottsboro area, a map of land capability was produced (Figure 10). Again a ten acre cell was used. No existing

TABLE III

	CROP	PASTURE	FOREST	WATER	OTHER
Acres	11,560	7,520	4,120	280	1,480
Percent	46.3	30.2	16.5	1.1	5.9

Land use at Site III, Redstone Airport area, Alabama in November, 1971. Analysis based on 40 acre cells using color infrared photography at a scale of 1:60,000.

classification scheme seemed appropriate to data acquisition from the imagery. Therefore, a classification was developed to gain maximum information from the photographs, modified from the USDA classification system as listed in Rehder, Delineation of Information Requirements by T.V.A. Interviews, Technical Report 71-2, December, 1971, p. 11-12. In Table V this land capability classification is listed along with the comparable USDA classes and the results for the Scottsboro area.

Imagery of this scale shows great promise in land use mapping and monitorization. Undoubtedly it should be an easy task to identify crops by type as well as types of pasture once a training set of ground data is provided. To illustrate, if a field of a certain tone and texture was known to a certain crop then all other fields of similar appearance on the imagery should be the same crop. However, further study is needed to document variation in a crop's appearance between areas. As illustrated in Tables IV and V and Figures 9 and 10, land use and land capability information can be obtained using imagery of this scale.

Imagery Comparisons

From the set of imagery used for interpretation the following comparisons were made: (1) film type--color versus color infrared, (2) scale--1:60,000 and 1:120,000, and (3) season--May and November. Before making comparisons let us look at the related interpretation problems.

Our facilities did not allow the comparisons to be as exact as possible. Recall that we were using a grid cell approach, and it was difficult to place the grid over two images at exactly the same position. Since the images produced at different times did not have identical scales, and any given point on the ground appeared in a different part on each image,

TABLE IV

DETAILED LAND USE

CATEGORY	SYMBOL	ACRES	PERCENT
Crop, rows visible, flat	C1a	50	0.6
Crop, rows visible, sloped	C1b	270	3.0
Crop, rows visible, drainage problem	C1c	10	0.1
Crop, strip farming, flat	C2a	0	0.0
Crop, strip farming, sloped	C2b	0	0.0
Crop, strip farming, drainage problem	C2c	0	0.0
Crop, no rows visible, flat	C3a	0	0.0
Crop, no rows visible, sloped	C3b	50	0.6
Crop, no rows visible, drainage problem	C3c	0	0.0
Crop, cleared for silviculture, sloped	C4b	10	0.1
Pasture, improved, flat	P1a	170	1.9
Pasture, improved, sloped	P1b	1,020	11.4
Pasture, improved, drainage problem	P1c	20	0.2
Pasture, unimproved, flat	P2a	30	0.3
Pasture, unimproved, sloped	P2b	540	6.0
Pasture, unimproved, drainage problem	P2c	10	0.1
Forest, commercial evergreen	F1	290	3.2
Forest, noncommercial deciduous	F2	120	1.3
Forest, noncommercial mixed	F3	3,290	36.6
Forest, noncommercial evergreen	F4	30	0.3
Water	W	2,630	29.2
Other, settlement	O1	270	3.0
Other, transportation	O2	100	1.1
Other, mining or quarring	O3	50	0.6
Other, other industry	O4	40	0.4
TOTAL		9,000	100.0

Detailed land use at Site V, Scottsboro area, Alabama in November, 1971. Analysis based on 10 acre cells using color infrared photography at a scale of 1:60,000.

TABLE V

LAND CAPABILITY

LAND CAPABILITY CLASSIFICATION	COMPARABLE USDA CLASS	ACRES	PERCENT
A. High quality, arable land well drained	I, II	270	3.0
B. Arable land, manageable with constraints	III, IV		
1. Sloping		2,360	26.2
2. Poor drainage		250	2.8
C. Lands limited in agricultural use - not suited for cultivation, often forest covered with steep slopes, and thin, rocky soils	V, VI, VII, VIII	3,530	39.2
W. Water - land permanently covered with water	NOT APPLICABLE	2,590	28.8
TOTAL		9,000	100.0

Land capability at Site V, Scottsboro area, Alabama in November, 1971. Analysis based on 10 acre cells using color infrared photography at a scale of 1:60,000.

the congruence desired was often lacking. For example, a grid placed over one image would fit a second image well in one corner of the test site, but be as much as one cell off in the opposite corner of the site. Interpretation systems which project the images could bring two images more closely to identical scales and should solve at least part of this problem.

Another problem is strictly one of human interpretation. It is the problem of determining a category for the "border line" situation. A cell where land use is equally divided between two or more categories must be placed in some category. Therefore, an equally valid decision might place a given cell in one category for one image and a different category on another image. Both the congruence problem and the category determination problem can result in major differences for an individual cell; however, it is important to note that only minor differences occur when percentages of land use for larger areas such as the test sites are considered.

Moreover, both the problem of scale and image congruence can be eliminated in the following manner. Using one image set as a base, a dot could be placed in the dominant land use in that cell. Location keys such as roads and road intersections, bridges or urban buildings would also be pinpointed on the grid. Then, on future flights, the resulting imagery would be displayed on a screen or mechanical enlarger. Then by enlarging or reducing the scale of this image to fit the grid previously derived, data error should be reduced to a minimum.

Usually, the five categories--crop, pasture, forest, water, and other--were fairly easy to distinguish. However, crop and pasture were often difficult to discern, and this difficulty was also the source of some error. In almost all cases these two categories contain the greatest variation. It is believed that this problem could be virtually eliminated if ground data were available for use as a training set.

A comparison of film type at Site III, Redstone Airport area, Alabama, documented the well known value of color infrared over color film for most land use analysis (see Figures 4 and 5). Both images were produced simultaneously in May of 1971, at the scale of 1:120,000. Table VI provides a summary of the results. At first glance the results appear similar. Note that the percentages in all categories are no more than one percent different from each other, and in two cases, water and other, the same figure was obtained for both images. The percentages are as follows: crop - 54.3 on color and 55.1 on color infrared; pasture - 28.9 on color and 29.1 on color infrared; forest - 12.8 on color and 11.8 on color infrared; water - 1.3 on both films; and other - 2.7 on both films.

However, boundaries between land use types were much more clearly defined on the color infrared. This fact became obvious when attempting to delimit a forest-pasture boundary. It was difficult in some cases to follow the boundary on the color film but easy on the color infrared film.

For the scale comparison the same site, Redstone Airport area, Site III, was used. Constant in this study are both time (i.e. November, 1971) and film (i.e. color infrared). See Figures 6 and 7. Of course, a great deal more detail is present on the 1:60,000 scale imagery, than on the 1:120,000 scale imagery. As noted earlier, a cell is four times as large on the 1:60,000 scale. It was only natural to think that the larger

TABLE VI

FILM TYPE COMPARISON

FILM TYPE	CROP	PASTURE	FOREST	WATER	OTHER
Color Acres Percent	 13,560 54.3	 7,200 28.9	 3,200 12.8	 320 1.3	 680 2.7
Color Infrared Acres Percent	 13,760 55.1	 7,240 29.1	 2,960 11.8	 320 1.3	 680 2.7

Land use at Site III, Redstone Airport area, Alabama in May, 1971. Analysis based on 40 acre cells using color and color infrared photography at a scale of 1:120,000.

scale would provide better information, and this example was no exception. The figures in Table VII reveal a difference, especially in the crop and pasture classes, and support this conclusion. For the crop category the percentages are 46.3 on the 1:60,000 scale and 42.1 on the 1:120,000 scale image; for the pasture category the percentages are 30.1 and 38.1 respectively. The difficulty involved in distinguishing between these two land use types has already been discussed. As noted in the section dealing with the 1:60,000 scale imagery, more detail was present in this larger scale imagery. Consequently, the interpretation was not only easier but decisions were probably more accurate since ground data were lacking.

The last comparison made was one between two different times of the year (Figures 5 and 7). Analysis of both Site II, Moulton-Courtland area, Alabama, and Site III, Redstone Airport area, Alabama, were used. The first flight was in May and the later one in November, 1971. Imagery from both dates had an approximate scale of 1:120,000. However, there was some scale variation, and the image pairs do not congruence exactly. An important question to consider here is how well can the changes in land use be monitored by this method? It is realized that six months is a very short period of time when some aspects of land use change are considered. Most likely a period of one to five years would be used in an operational system. Also, it is not known at this time whether either May or November is an optimum month for land use studies. Nevertheless, this study does provide a basis to evaluate the potential of using 1:120,000 color infrared photography to monitor land use over time.

Note in Table VIII the figures for the seasonal comparison. Here again, there is greater discrepancy in the crop and pasture classes than in any other, as should be expected. In the crop category there is a

TABLE VII

IMAGERY SCALE COMPARISON

SCALE	CROP	PASTURE	FOREST	WATER	OTHER
1:60,000					
Acres	11,560	7,520	4,120	280	1,480
Percent	46.3	30.1	16.5	1.2	5.9
1:120,000					
Acres	10,520	9,520	3,800	280	840
Percent	42.1	38.1	15.2	1.2	3.4

Land use at Site III, Redstone Airport area, Alabama, in November, 1971. Analysis based on 40 acre cells using color infrared photography at scales of 1:60,000 and 1:120,000.

higher figure in May, while in the pasture category there is a higher figure in November. Part of this discrepancy lies in the scale problem and part in the contrast in the appearance of the vegetative cover between May and November. Since it is not known whether May or November is a better time to detect land use, due to a lack of ground based data, it is difficult to decide which month provides the best information. Yet, a change in land use was detected. This suggests that imagery of this scale (1:120,000) could be useful in monitoring land use change over time.

Summary and Conclusions

In this study we have attempted to evaluate the potential of hyper-altitude and space photography for land use mapping with regard to requirements of the Tennessee Valley Authority. This consisted of an analysis of color infrared photography obtained at three different scales over northern Alabama in November, 1971, and an earlier supplemental flight in May of the same year. In each case the imagery was analyzed to determine the amount of detailed data obtainable and its possible application in monitoring land use. However, it should be remembered that a lack of simultaneous ground data to compare with the imagery severely restricted our efforts. It is felt that each type of imagery has unique advantages in studying land use and its changes.

Imagery at a scale of 1:340,000 and smaller, e.g. space photography, is useful in defining the limits of agricultural subsystems within topographic units such as drainage basins. Over long time periods a comparison of such imagery should illustrate where land use patterns have been altered. For example, it should be possible to detect areas that have shifted from primarily crop to pasture activity, cultivated

TABLE VIII

SEASONAL COMPARISON

SITE AND DATE	CROP	PASTURE	FOREST	WATER	OTHER
Site II, Moulton-Courtland					
May, 1971					
Acres	4,520	8,560	11,760	40	80
Percent	18.1	34.3	47.1	0.2	0.3
November, 1971					
Acres	3,720	8,880	12,280	0	80
Percent	14.9	35.6	49.2	0.0	0.3
Site III, Redstone Airport					
May, 1971					
Acres	13,760	7,240	2,960	320	680
Percent	55.1	29.1	11.8	1.3	2.7
November, 1971					
Acres	10,520	9,520	3,800	280	840
Percent	42.1	38.1	15.2	1.2	3.4

Land use for two different times of the year, May and November, are compared for Site II, Moulton-Courtland area, Alabama, and Site III, Redstone Airport area, Alabama, based on 40 acre cells. All images are color infrared at a scale of 1:120,000.

areas that have reverted to forest or natural vegetation, the extent of urban expansion, or other phenomena of a regional nature. Once these regional variations are noted a more detailed analysis of that region can be initiated using larger scale imagery.

As illustrated in Figures 2, 3, 4, 5, 7, 8, 11, and 12, imagery at a scale of 1:120,000 can be used to determine how the land is presently being used in the TVA region. Using 40 acre cells, land was placed in one of four categories: crop, pasture, forest, and other. This approach permits quick calculation of acreages as well as offering a method to record fairly detailed changes in land use over any time period desired, provided imagery is obtained. It is believed that certain crop types, forest types, and classes of pasture could be identified with imagery of this scale if ground data were available. To illustrate, if a certain field is known to contain corn then all other fields in the region of similar appearance on the imagery could also be classified as corn and an estimate made of the acreage, using the grid method described earlier. Landforms and areas of soil erosion are also detectable on this imagery.

The 1:60,000 scale imagery is particularly adaptable to detailed land use surveys. As can be seen in Figures 9 and 10, modified versions of the USDA Land Capability Classification as well as land use types can be identified from such imagery, but an exact duplication of the land capability classes is probably not possible. Indeed, it is difficult to accomplish on the ground. However, a modified version is possible that can then be incorporated into the detailed classification by ground checking. Twenty-five land use types were detectable from this scale imagery. This is particularly encouraging since no ground data were available. Once ground data is available for use as a training set it is believed that this imagery can provide a quick accurate picture of how land resources are presently being used. Other data detectable at this scale include landform types and areas of surface erosion.

In summary it is believed that remote sensing can fulfill at least some of the land use information needs of the TVA. Imagery of these scales can be used to monitor the extent and progress of urban sprawl and the change in agricultural land use around these urban areas. More importantly, it is possible to identify present land use and detect changes in agricultural and nonagricultural land use over time. Lastly, information regarding types of landforms, extent of surface erosion, and a limited land classification and capability analysis are obtainable.

Recommendations

In light of the encouraging results of this study the following items list areas where future work might be concentrated.

1. The incorporation of ground data collected at the same time that imagery was obtained. These data should then be studied in connection with all three scales of imagery to determine what information increases result regarding crop type identification.

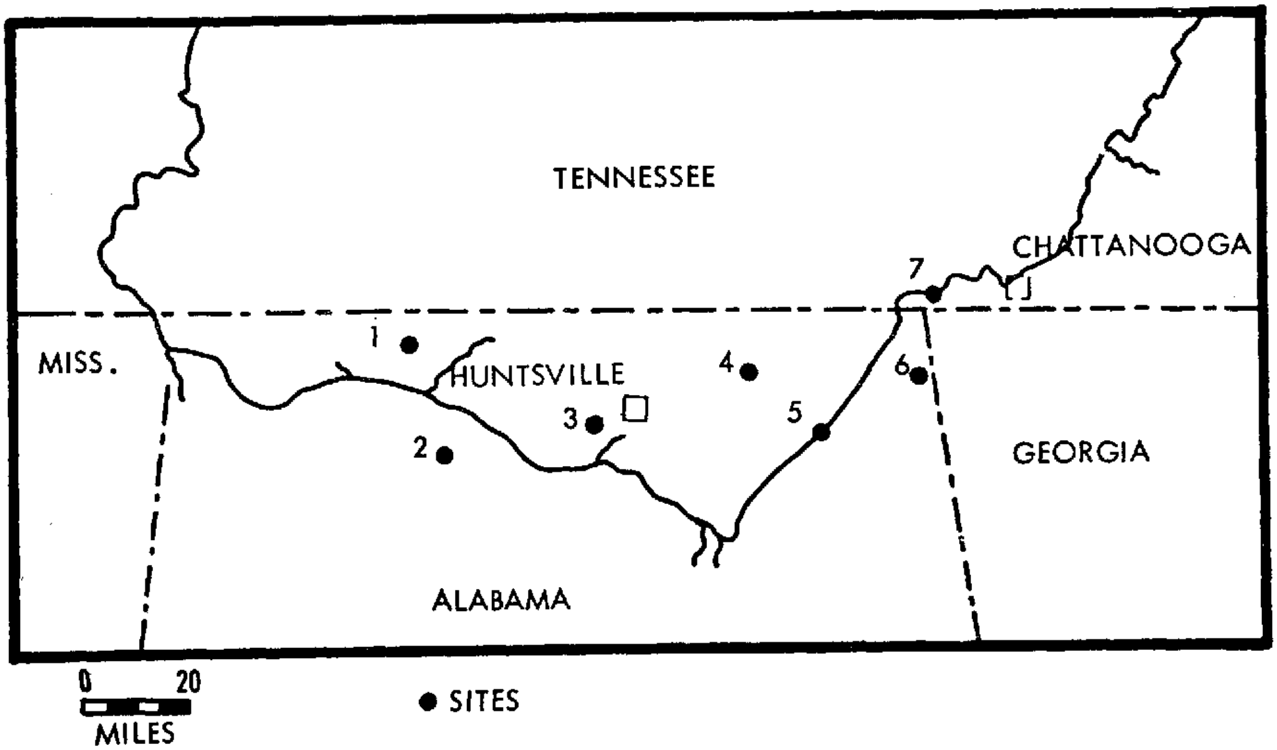
2. Imagery should be obtained at various times of the year to ascertain which if any is the optimal time, i.e. month, for detection of crop type or surface erosion. For example, the best time to calculate cultivated land acreage might be after spring plowing when recently tilled fields can be easily identified. Erosion might be most readily detected in those months when ground cover is at a minimum.

3. Attempts should be made to see if it is possible to define land capability in greater detail using 1:60,000 scale imagery. Specifically, TVA personnel and interpretors should work together to create more distinct classes susceptible to identification from imagery.
4. The feasibility of automating land use information, obtained by remote sensing, for rapid retrieval and processing should be studied and the economic aspects determined.
5. The results obtained in this study should be compared with similar studies in other regions and larger regions of the TVA to determine their overall validity and practicality.

The results of this study seem promising. It is hoped that future work will enlarge on these preliminary observations and further document the role of remote sensing for land use analysis in the TVA.

Figure 1.

LAND USE TEST SITES

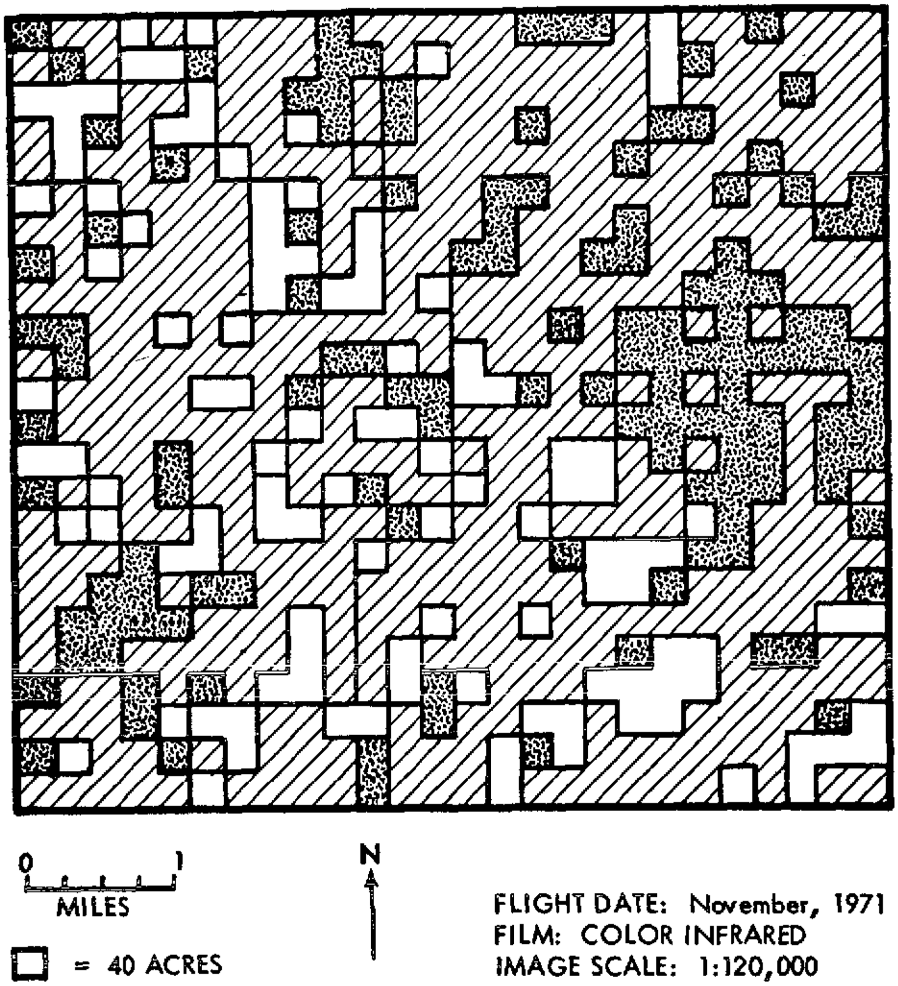


1. NEAR ANDERSON, ALABAMA
2. MOULTON-COURTLAND AREA, ALABAMA
3. REDSTONE AIRPORT AREA, ALABAMA
4. HOLLYTREE-PAINTROCK RIVER AREA, ALABAMA
5. SCOTTSBORO AREA, ALABAMA
6. SAND MOUNTAIN AREA, ALABAMA
7. HALES BAR AREA, TENNESSEE

Figure 2.

LAND USE IN AREA I

NEAR ANDERSON, ALABAMA



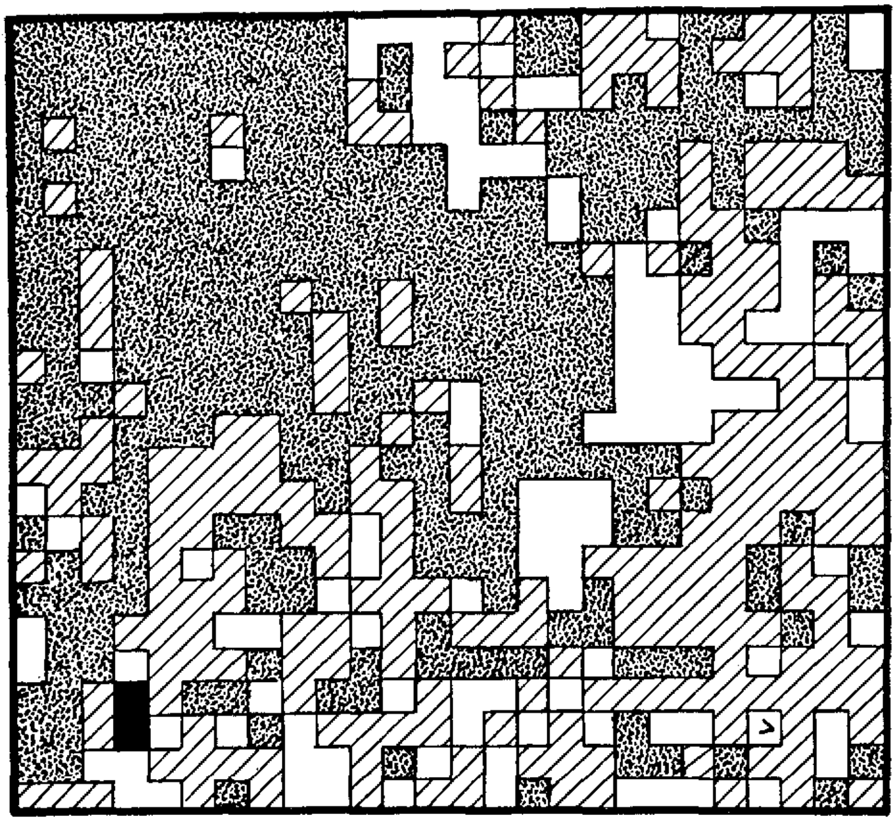
FLIGHT DATE: November, 1971
FILM: COLOR INFRARED
IMAGE SCALE: 1:120,000

	ACRES	PERCENT
CROP	4,240	17.0
PASTURE	15,320	61.4
FOREST	5,200	20.8
WATER	80	0.3
OTHER	120	0.5
TOTAL	24,960	100.0

Figure 3.

LAND USE IN AREA II

(NEAR MOULTON-COURTLAND, ALA.)



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MILES

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FLIGHT DATE: May, 1971
FILM: COLOR INFRARED
IMAGE SCALE: 1:120,000

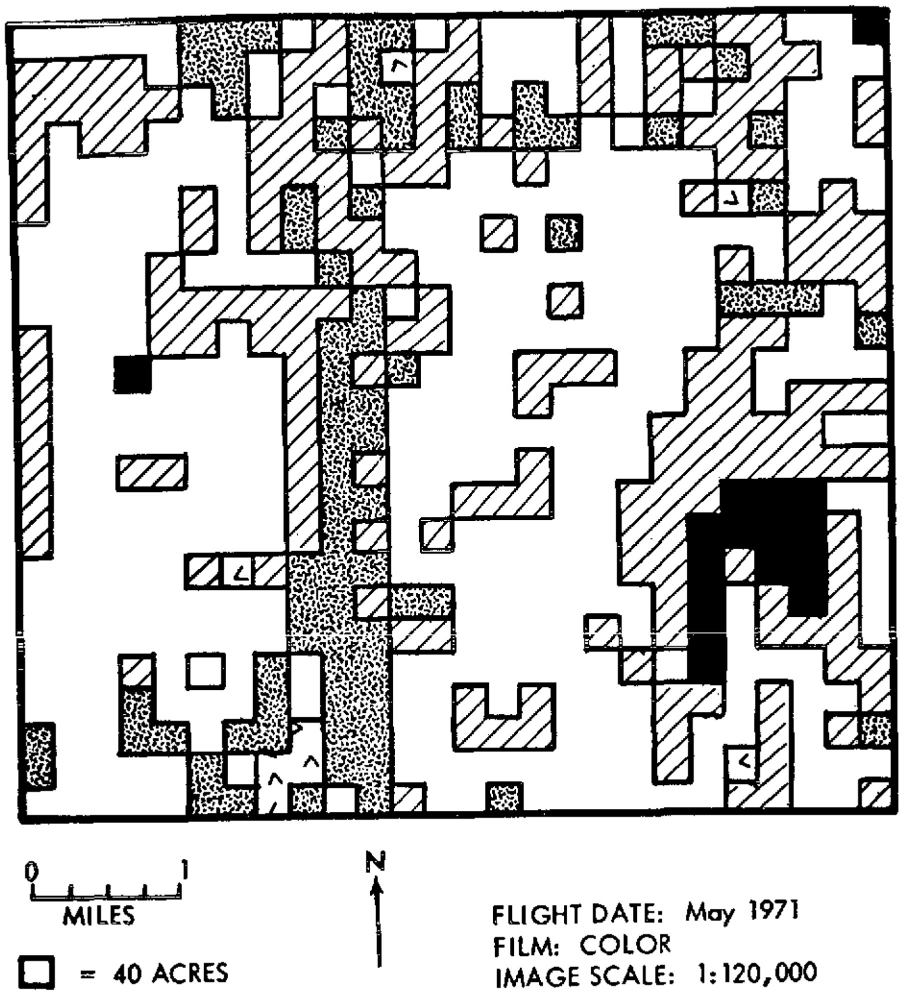
= 40 ACRES

		ACRES	PERCENT
	CROP	4,520	18.1
	PASTURE	8,560	34.3
	FOREST	11,760	47.1
	WATER	40	0.2
	OTHER	80	0.3
	TOTAL	24,960	100.0

Figure 4.

LAND USE IN AREA III

(REDSTONE AIRPORT AREA, ALA.)



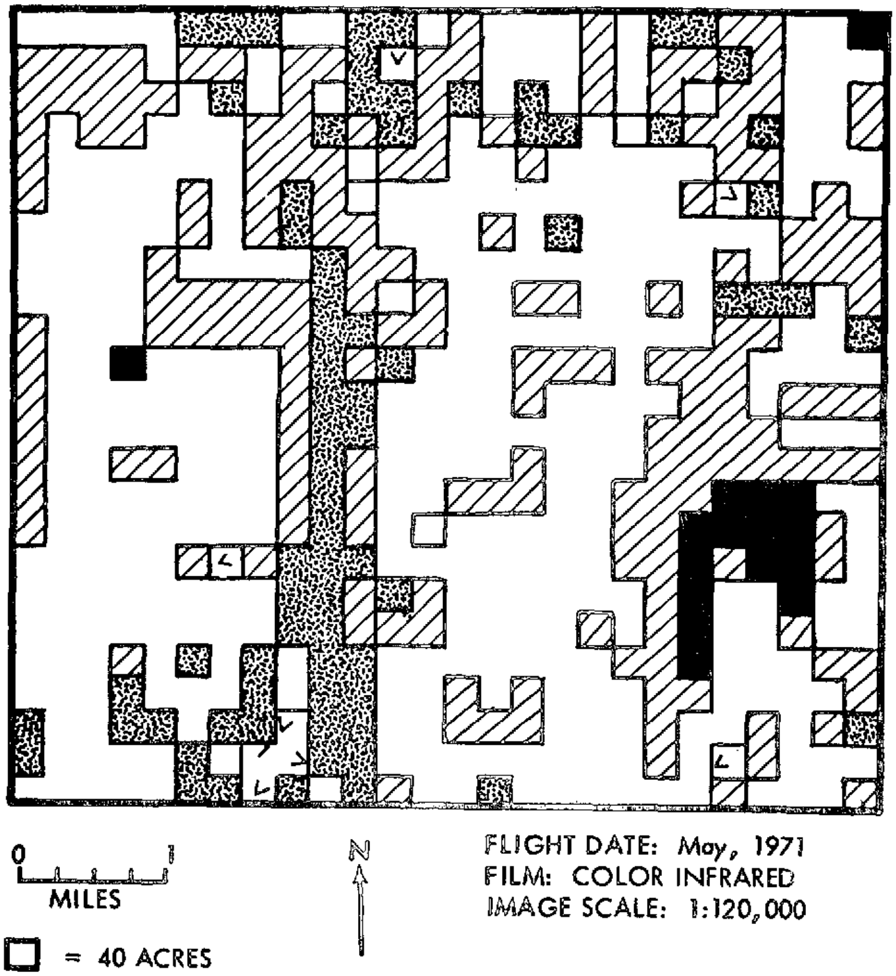
FLIGHT DATE: May 1971
FILM: COLOR
IMAGE SCALE: 1:120,000

		ACRES	PERCENT
	CROP	13,560	54.3
	PASTURE	7,200	28.9
	FOREST	3,200	12.8
	WATER	320	1.3
	OTHER	680	2.7
	TOTAL	24,960	100.0

Figure 5.

LAND USE IN AREA III

(REDSTONE AIRPORT AREA, ALA.)

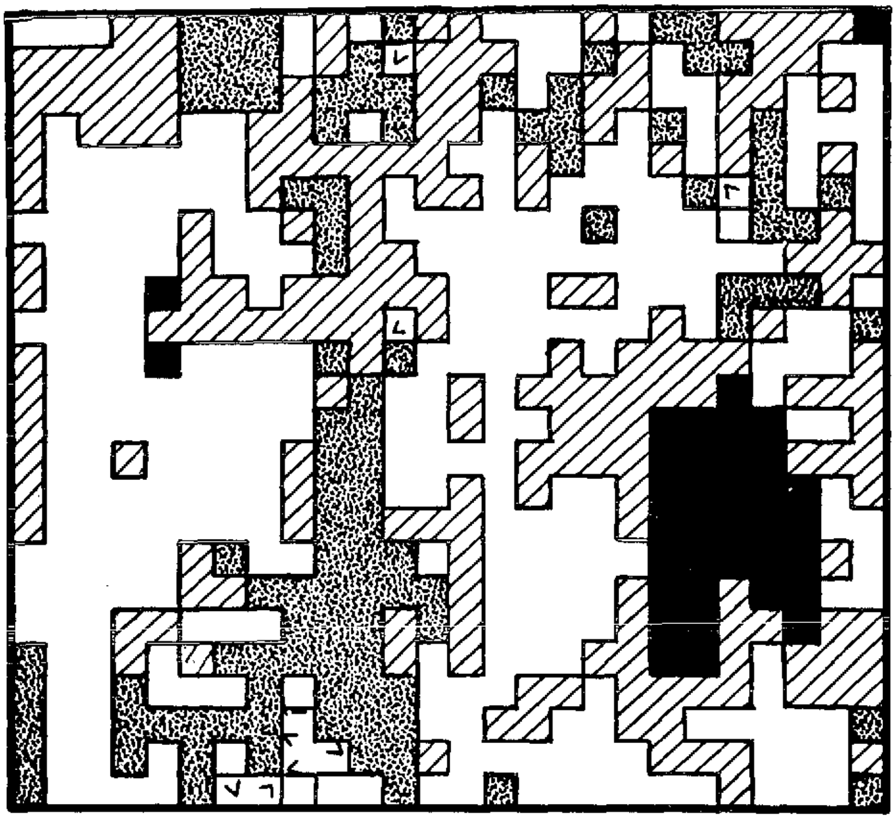


FLIGHT DATE: May, 1971
FILM: COLOR INFRARED
IMAGE SCALE: 1:120,000

		ACRES	PERCENT
	CROP	13,760	55.1
	PASTURE	7,420	29.1
	FOREST	2,960	11.8
	WATER	320	1.3
	OTHER	680	2.7
	TOTAL	24,960	100.0

Figure 6.

LAND USE IN AREA III
(REDSTONE AIRPORT AREA, ALA.)



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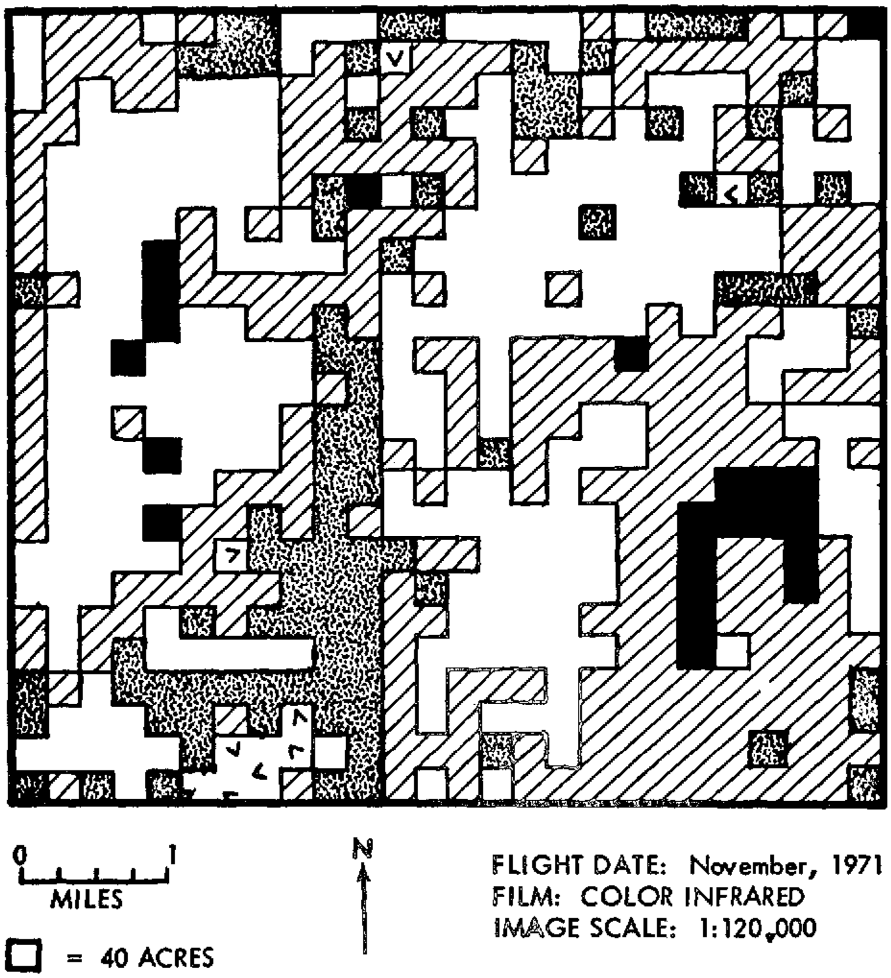
☐ = 40 ACRES

FLIGHT DATE: November, 1971
FILM: COLOR INFRARED
IMAGE SCALE: 1:60,000

	ACRES	PERCENT
CROP	11,560	46.3
PASTURE	7,520	30.2
FOREST	4,120	16.5
WATER	280	1.1
OTHER	1,480	5.9
TOTAL	24,960	100.0

Figure 7.

LAND USE IN AREA III
(REDSTONE AIRPORT AREA, ALA.)

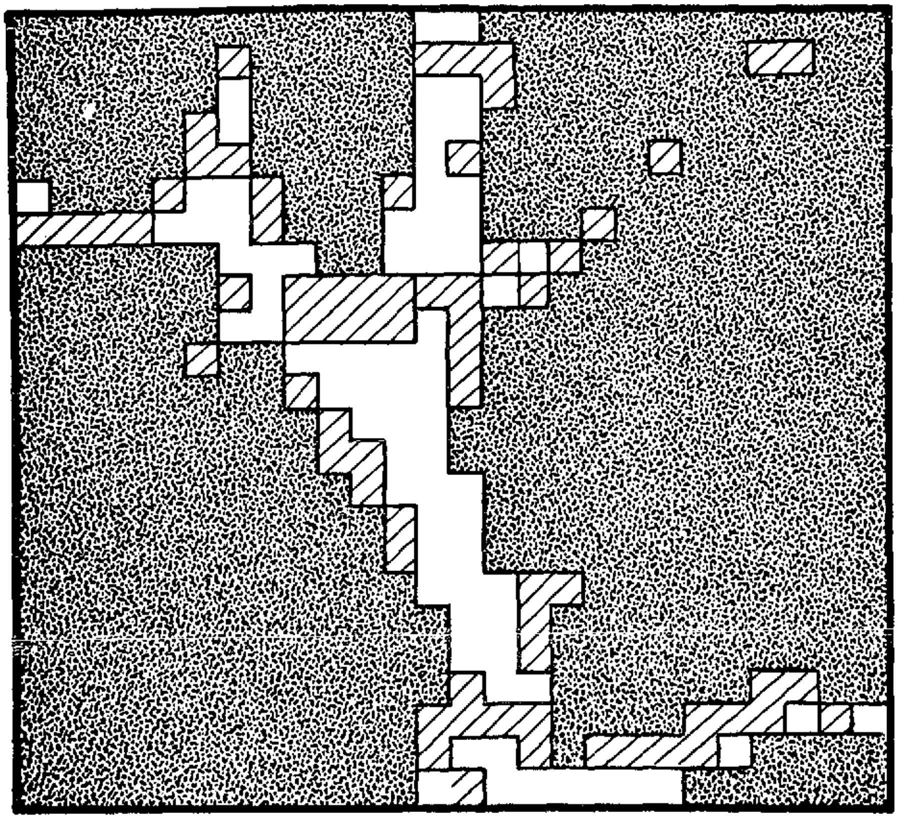


		ACRES	PERCENT
	CROP	10,520	42.1
	PASTURE	9,520	38.1
	FOREST	3,800	15.2
	WATER	280	1.2
	OTHER	840	3.4
	TOTAL	24,960	100.0

Figure 8.

LAND USE IN AREA IV

HOLLYTREE-PAINT ROCK RIVER AREA, ALABAMA



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☐ = 40 ACRES

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FLIGHT DATE: November, 1971
FILM: COLOR INFRARED
IMAGE SCALE: 1:120,000

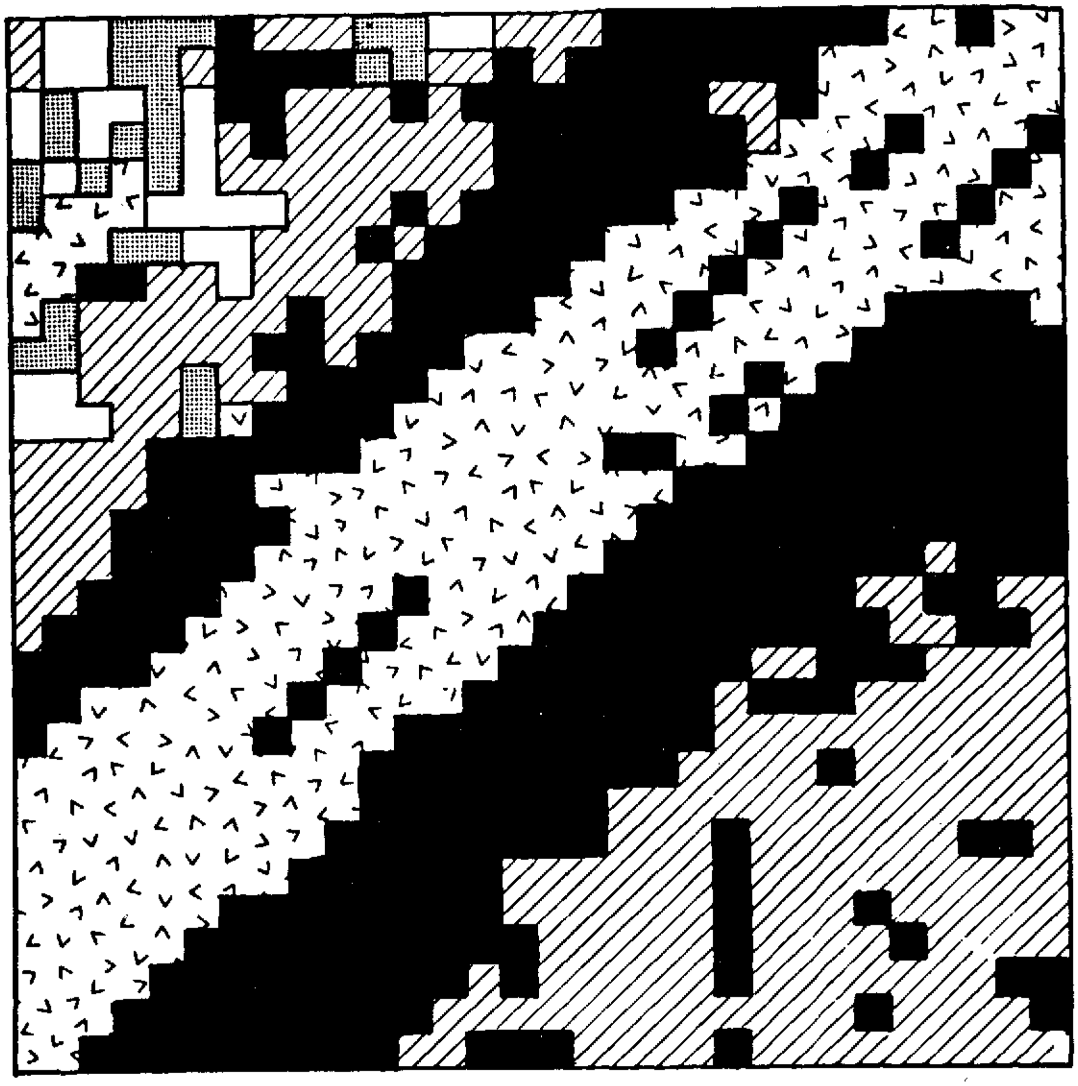
	ACRES	PERCENT
CROP	2,960	11.9
PASTURE	2,720	10.9
FOREST	19,280	77.2
WATER	0	0.0
OTHER	0	0.0
TOTAL	24,960	100.0

Figure 9.

AREA V

LAND CAPABILITY CLASSIFICATION

SCOTTSBORO AREA, ALABAMA



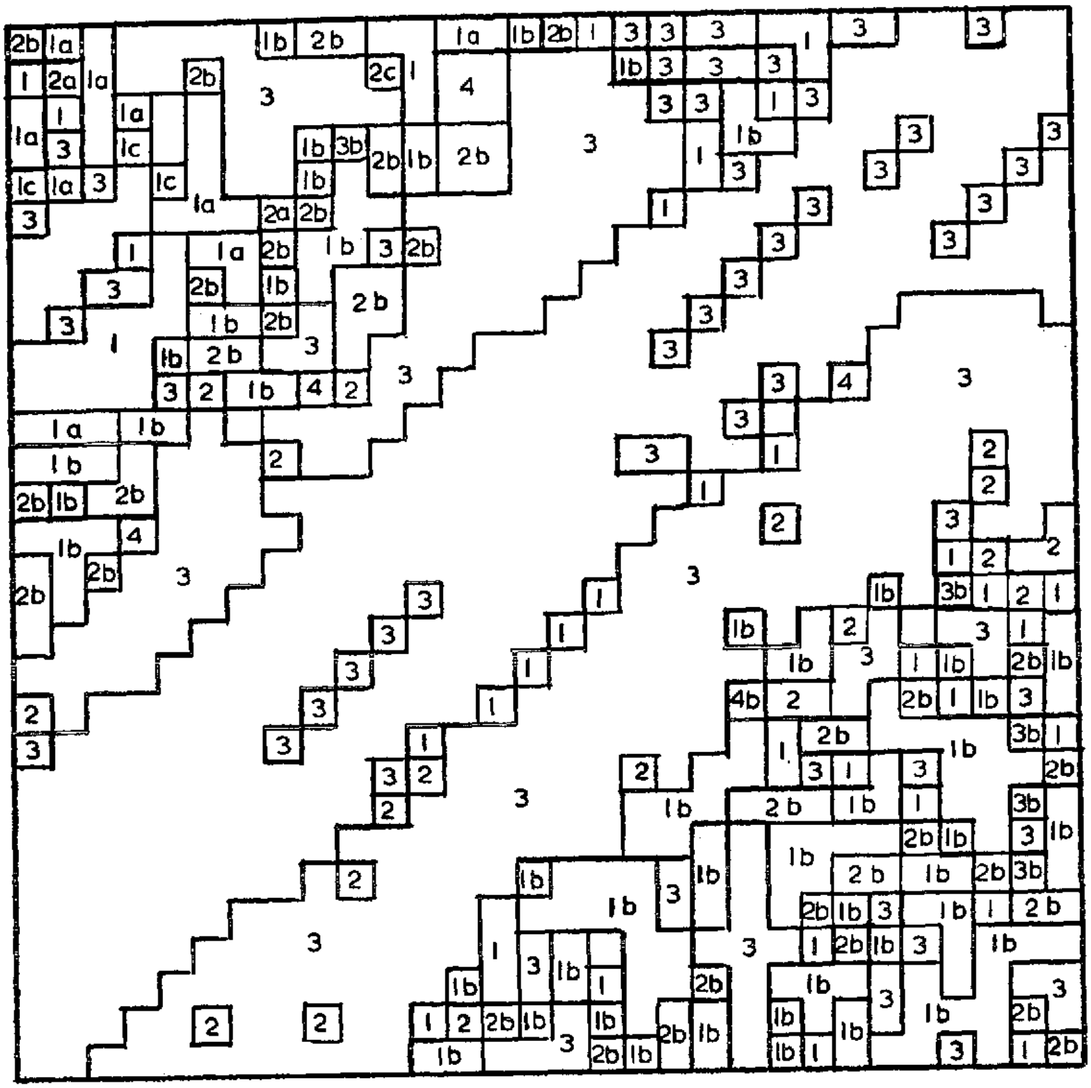
10 ACRES

FLIGHT DATE: November, 1971
FILM: COLOR INFRARED
IMAGE SIZE: 1:60,000

	ACRES	PERCENT
WATER	270	3.0
HIGH QUALITY ARABLE LAND	2,360	26.2
ARABLE LAND-SLOPING	250	2.8
ARABLE LAND-POOR DRAINAGE	3530	39.2
LIMITED AGRICULTURAL USE	2,590	28.8
	9 000	100.0

CLASSES OF DETAILED LAND USE FOR

FIGURE 10 (OPPOSITE PAGE)*



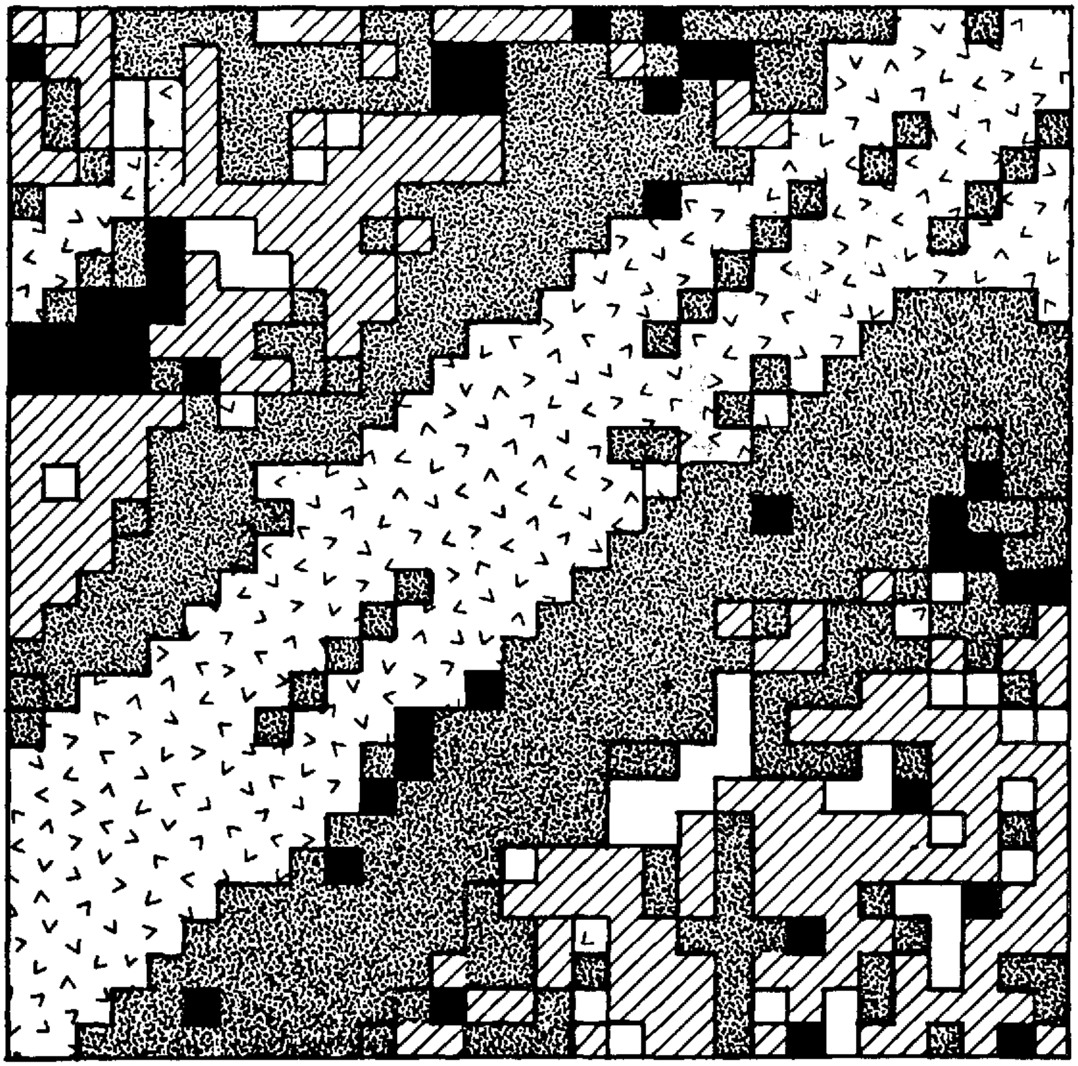
*FOR DEFINITION OF CLASSES SEE TABLE IV

Figure 10.

AREA V

DETAILED LAND USE

SCOTTSBORO AREA, ALABAMA



□ 10 ACRES

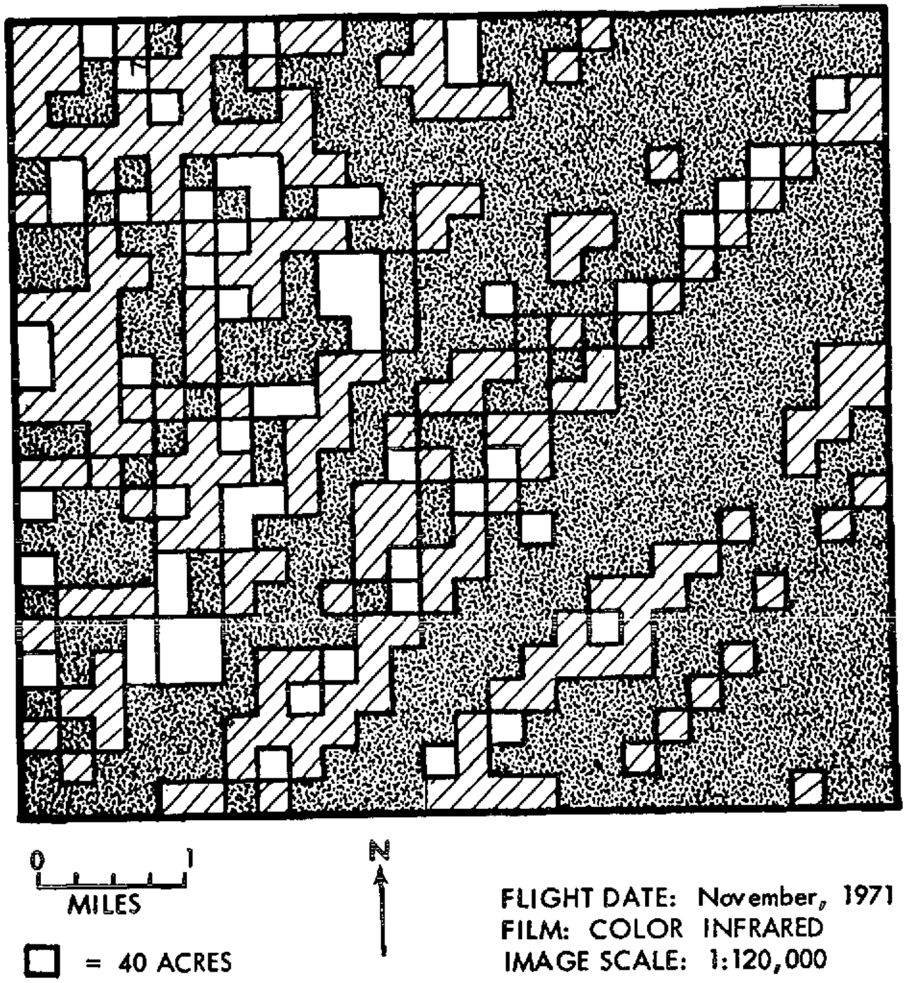
FLIGHT DATE: November, 1971
FILM: COLOR INFRARED
IMAGE SIZE: 1:60,000

	ACRES	PERCENT
CROP	390	4.3
PASTURE	1,790	19.9
FOREST	3,730	41.5
WATER	2,630	29.2
OTHER	460	5.1

Figure 11.

LAND USE IN AREA VI

SAND MOUNTAIN AREA, ALABAMA



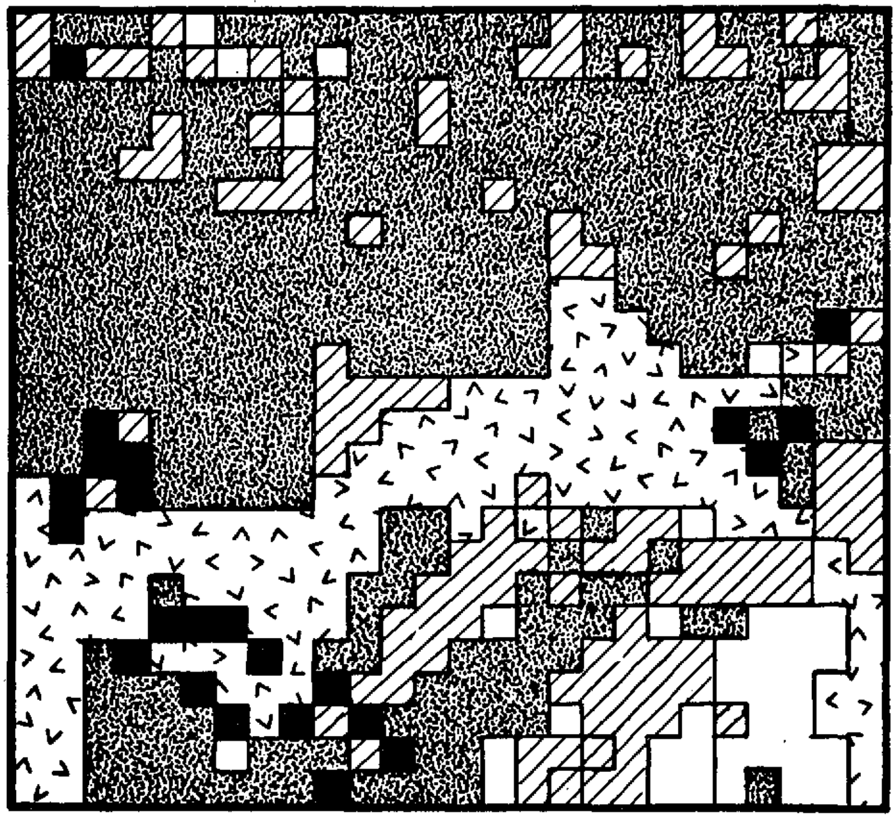
FLIGHT DATE: November, 1971
FILM: COLOR INFRARED
IMAGE SCALE: 1:120,000

	ACRES	PERCENT
CROP	1,680	6.7
PASTURE	7,780	31.6
FOREST	14,760	59.1
WATER	40	0.2
OTHER	600	2.4
TOTAL	24,960	100.0

Figure 12.

LAND USE IN AREA VII

HALES BAR SITE, TENNESSEE



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☐ = 40 ACRES

FLIGHT DATE: November, 1971
FILM: COLOR INFRARED
FILM IMAGE: 1:120,000

		ACRES	PERCENT
	CROP	1,480	5.9
	PASTURE	4,440	17.8
	FOREST	13,000	52.1
	WATER	5,080	20.4
	OTHER	960	3.8
	TOTAL	24,960	100.0

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